

**[001]     HEAT-SEALING METHOD AND DEVICE FOR IMPLEMENTING SAME**

**[002]**

**[003]     Technical Domain**

**[004]**             The instant invention concerns a method for heat-sealing at least one film of synthetic thermoplastic material to a container made of at least one synthetic thermoplastic material, particularly a container for packaging products that are susceptible to microbiological contamination, more specifically, biological or perishable commodities such as agricultural produce, said method using at least a first and a second thermal electrode.

**[005]**             It also concerns a device for heat-sealing at least one film of synthetic thermoplastic material onto a container made of at least one synthetic thermoplastic material, particularly a container for packaging products susceptible to microbiological contamination, more specifically, biological or perishable commodities such as agricultural produce, using at least a first and a second thermal electrode to implement this method.

**[006]     Prior Art**

**[007]**             Numerous packages, particularly those designed for packaging food produce, are formed of a pouch consisting of two thermoplastic films sealed together or formed of a container made of one or more synthetic materials manufactured by heat-sealing and closed by sealing thermoplastic film onto the container using heating electrodes. Although steady improvements have been made with respect to barrier-type films, the weakest link in package sealing remains the joining of thermoplastic films to each other or joining a thermoplastic film or lid to a thermoplastic package. At high speed and using current techniques, neither the seal nor consumer safety standards relative to the microbiological aspect of food packaging are completely satisfactory.

**[008]**             Thermoplastic film is normally composed of a sealing layer which, after heating and at a given pressure, forms tight contact with the other portion to which it is joined. During contact, heat sufficient to bring the sealing layer to its

melting point is transmitted to the materials. The pressure maintained during sealing crushes the sealing layer, which spreads and thins out. When the thin layer of sealing material crystallizes upon application of some sort of mechanical constraint, it sometimes pulls away, causing the formation of cracks which destroy the microbiological integrity of the packaging.

**[009]** The principal problems contributing to this result have been identified. They relate primarily to the heat. Heat regulation is essentially arbitrary, with the result that there is little control over the energy transmitted by the thermal electrodes to the material, causing the sealing layer to possibly overheat, spread excessively, and leading to increased shrinkage by the material. Furthermore, the randomness of the heat control also results in excessively long production cycles, detracting from the efficiency of the production line.

**[010]** Various techniques exist for sealing film with heat, for example, the use of heating bars, hot wires, or heat impulsion. These different techniques are not suitable for all types of polymers used as synthetic heat-sealable material. It is necessary to take into account the surfaces to be sealed, their various thicknesses, the coating on the materials, etc. The high speeds requirements of current production techniques often limit sealing time to less than a second. The application of either excessive or insufficient amounts of heat detracts from the quality of sealing. Current technical improvements are principally based on more precise temperature control of the heating bars. Data on the behavior of sealed polymers is only available for laboratory settings using destructive protocols. There is currently no device for dynamic control of sealing on production lines.

**[011]** The principal flaws of these known systems are due to:

**[012]** Too much thermal inertia in the sealing systems;

**[013]** Very low thermal stability of the sealing bars;

**[014]** Too much pressure applied to the film to be heat-sealed;

**[015]** Lack of control over the heat-sealing process on the line;

**[016]** Lack of control over cooling the seal on the line; and

**[017]** No regulation on the basis of the state of the synthetic material used.

**[018] Description of the Invention**

**[019]** The instant invention proposes overcoming the disadvantages of the prior art by offering a high quality heat-sealing method that respects the microbiological integrity of a package.

**[020]** This goal is achieved by the method of the invention as defined in the preamble and characterized in that:

**[021]** At least the first electrode is stabilized by controlling the variation in thermal flux emitted by this electrode;

**[022]** Temperature variation between the two electrodes is regulated by controlling the thermal flux flowing between said first and second electrodes, said thermal flux resulting from the temperature disequilibrium between the two electrodes and the variation in thermal resistance corresponding to the physical state of the synthetic thermoplastic material.

**[023]** The pressure exerted by at least one of the electrodes on the synthetic thermoplastic material is regulated by controlling the instantaneous variation in thermal flux resulting from the thermal energy absorbed by the melting of the synthetic thermoplastic material.

**[024]** A device for cooling the synthetic thermoplastic material is regulated by controlling the instantaneous variation of thermal flux resulting from the thermal energy restored by the synthetic thermoplastic material when it crystallizes.

**[025]** Advantageously, said first thermal electrode is first stabilized and the temperature difference between the two electrodes is regulated by controlling the heat flux using at least one heat flux sensor associated with said thermal electrodes.

**[026]** Preferably the pressure exerted by at least one thermal electrode on the synthetic thermoplastic material is regulated using at least one cylinder associated with this electrode and cooling of the synthetic thermoplastic material is regulated by chilling at least one of the thermal electrodes.

**[027]** The device as defined in the preamble for implementing this method is characterized in that it comprises:

- [028]** A means for stabilizing at least the first thermal electrode by controlling the variation in heat flux emitted by said electrode;
- [029]** A means for regulating the temperature difference between the two electrodes by controlling the heat flux flowing between the first and the second electrode, said heat flux resulting from the temperature disequilibrium between the two electrodes and the variation in thermal resistance corresponding to the physical state of the synthetic thermoplastic material;
- [030]** A means for regulating the pressure exerted by at least one of the electrodes on the synthetic thermoplastic material by controlling the instantaneous variation in heat flux resulting from the thermal energy absorbed by the melting of the synthetic thermoplastic material; and
- [031]** A means for regulating a device for cooling the synthetic thermoplastic material by controlling the instantaneous variation in heat flux resulting from the thermal energy restored by the synthetic thermoplastic material when it crystallizes.
- [032]** In a preferred form of embodiment said means for stabilizing at least said first thermal electrode by controlling the variation in heat flux emitted by said electrode comprises a heat flux sensor and a thermal flux meter regulator associated with this thermal electrode.
- [033]** In this same embodiment, said means for regulating a temperature differential between the two electrodes by controlling the heat flux flowing between said first and said second electrode, said heat flux resulting from the temperature disequilibrium existing between the two electrodes and the variation in thermal resistance corresponding to the physical state of the synthetic thermoplastic material, comprises at least one heat flux sensor associated with each of the thermal electrodes and a thermal flux meter regulator connected to these sensors and to these electrodes.
- [034]** Advantageously, said means for regulating the pressure exerted by at least one of said electrodes on the thermoplastic material by controlling the instantaneous variation of heat flux resulting from the thermal energy absorbed

by the melting of the synthetic thermoplastic material comprises a cylinder associated with said thermal electrode.

**[035]** Preferably said means for regulating a device for cooling the synthetic thermoplastic material by controlling the instantaneous heat flux variation resulting from the thermal energy restored by the synthetic thermoplastic material when it crystallizes comprises at least one cooling channel formed inside at least one of said thermal electrodes.

**[036]** In an advantageous embodiment, at least one of the thermal electrodes comprises a heating bar.

**[037]** According to a variation, at least one of the thermal electrodes may comprise a thermal capacitor.

**[038]** Preferably at least one of the thermal electrodes is attached to a flexible block and housed inside said flexible block which is attached to a support on the heat sealing device.

**[039]** Advantageously said thermal electrode may comprise an integrated resistor element.

**[040]** Said device is not intended uniquely for controlling and guiding the sealing of food packaging, but for any thermoplastic film sealing process where improved sealing quality is sought. Its applications are broad and may extend to medical devices (transfusion pouches), or to thick injected containers and lids, for example. It is also possible with this device to control the strength of seal delamination and peeling.

**[041] Summary Description of the Drawings**

**[042]** The features of the present invention will be more apparent from the following description of different modes of implementing the method and different embodiments of the device of the invention, with reference to the attached drawings, in which:

**[043]** Figure 1 is a schematic view of a heat-sealing device;

**[044]** Figures 1A and 1B are perspectives of two embodiments of thermal

- electrodes that can be used with the heat-sealing device of Figure 1;
- [045]** Figure 2 is a cross-section of one example of films made of synthetic thermoplastic material constituting multi-layer heat-sealable materials;
- [046]** Figure 2A is a cross-section of a package comprising a thermo-formed container and a heat-sealed lid;
- [047]** Figure 3 is an elevation of a first embodiment of a thermal electrode that can be used with the device of Figure 1;
- [048]** Figure 3A is a cross-section of said first embodiment of a thermal electrode shown in Figure 3;
- [049]** Figure 4 is an elevation of a second embodiment of a thermal electrode that can be used with the device of Figure 1;
- [050]** Figure 4A is a cross-section of said second embodiment of a thermal electrode shown in Figure 4;
- [051]** Figure 5 is an elevation of a third embodiment of a thermal electrode that can be used with the device of Figure 1;
- [052]** Figure 5A is a cross-section of said third embodiment of a thermal electrode shown in Figure 5;
- [053]** Figure 6 is an elevation of a fourth form of embodiment of a thermal electrode that can be used with the device of Figure 1;
- [054]** Figure 7 is a view showing the zone where the two heat-sealable materials are joined;
- [055]** Figure 8 is a view illustrating the heat-sealing principle for two heat-sealable materials at the same temperature;
- [056]** Figure 8A is a view showing the heat-sealing principle for two heat-sealable materials at different temperatures;
- [057]** Figure 9 illustrates the heat-sealing device equipped with its heat flux control and regulation elements;
- [058]** Figure 10 represents profile views of the thermal electrodes in the sealing zones;

**[059]** Figures 11 through 13 represent various forms of seals that can be obtained; and

**[060]** Figure 14 represents a particular application of the heat-sealing device according to the invention.

**[061] How to Achieve the Invention**

**[062]** With reference to Figure 1 the heat-sealing device 10 shown may comprise two thermal electrodes 11 and 12. A single thermal electrode may suffice for certain applications. These electrodes are generally made of a highly heat-conductive material such as, for example, aluminum or copper. Electrode 11 is held by a support 13 that is mounted on a pneumatic or electric pressure cylinder 14. Electrode 12 is rigidly attached to a support 15 integral with the machine frame (not shown). Support 15 may also be attached to a cylinder for certain specific applications.

**[063]** Figure 1A shows a first embodiment of thermal electrodes 11 and 12. They comprise a metal bar 11a and 12a each containing at least one integrated resistor element such as a heating wire 11b, 12b, respectively, or a heating stick, or the like.

**[064]** Figure 1B shows a second embodiment of thermal electrodes 11 and 12. They are in the form of blades 11c and 12c with a longitudinal slot 11d, 12d, respectively, covered with a heat-resistant film 11e, 12e, respectively.

**[065]** The temperature of thermal electrodes 11 and 12 is regulated on the basis of data furnished by sensors measuring the thermal energy required to effect heat-sealing.

**[066]** As shown in Figure 2, films 20 and 21 to be sealed are, for example, multi-layer films and may comprise a first exterior barrier layer 20a, 21a respectively, a first impression layer 20b, 21b, respectively, a second impression layer 20c, 21c, respectively, a second interior barrier layer 20d, 21d, respectively, and a sealing layer 20e, 21e, respectively. The sealing layer has a lower melting temperature  $T_F$  lower than the other layers, particularly the barrier layers. The

two contacting sealing layers 20e and 21e are sealed when they begin to melt, ensuring the cohesion of the unit.

**[067]** Figure 2A illustrates a package comprising a container 22 made from heat-formed or injected material and a barrier film 23 serving as a lid. This barrier film could also be replaced by an injected cover. Sealing can be effected with a single electrode applied to the lid, the sealing zone on container 22 having been previously preheated using hot air or an infrared beam.

**[068]** Figures 3 and 3A respectively illustrate an elevation and a cross-section of an embodiment of a thermal electrode called the sealing electrode 11 of device 10. It consists essentially of a metal section 30 that may be several millimeters wide and of variable length. It is made of electrically resistant material, for example, ferro-nickel that may or may not be coated with Teflon® film. Electrical connecting terminals 31 are located at the extremities of section 30. A heat flux sensor 32 is mechanically attached by its lower surface to the upper portion of section 30. Heat flux sensor 32 has two electrical connections 33. The upper surface of heat flux sensor 32 is attached to the lower surface of a thermal capacitor 34 made of material with high thermal conductivity and diffusivity. A thermocouple 35 is mounted in a cavity formed in metal section 30.

**[069]** Figure 3A shows more detail of the unit attached to a support connected to the heat-sealing device. Thermal capacitor 34 is housed in a flexible block 36 made of electrically insulating thermal material, for example, silicon rubber, said block being housed inside a recess in support 37 integral with the heat-sealing device. The unique feature of this flexible assemblage is its ability to overcome the tendency of thermal electrodes to be slippery.

**[070]** Figures 4 and 4A represent another embodiment of a thermal electrode, called sealing electrode 11, of device 10. This sealing electrode consists of a metal section 40 made of thermally conductive and highly diffusive material joined to a heating bar 41 made of electrically resistant material. This heating bar 41 is equipped with electrical connection terminals 42. The metal section 40 has a central groove 43 for housing a heat flux sensor 44, the lower portion of



which is attached to the upper surface of metal section 40, and the upper surface of which is attached to thermal capacitor 45 made of the same material as metal section 40 which constitutes the thermal electrode called the sealing electrode. Thermal capacitor 45 is joined below electrical heating bar 41. Heat flux sensor 44 has two electrical connections 46. A thermocouple 47 is attached to the inside of the sealing electrode.

**[071]** Figure 4A represents a cross-section of this thermal electrode. As with the embodiment in Figures 3 and 3A, the unit consisting of metal section 40, heating bar 41, thermal capacitor 45, and heat flux sensor 44 is housed in a flexible block 48. Flexible block 48 itself is housed in a support element 49 for the heat-sealing device. The unique feature of this flexible assemblage is its ability to overcome the tendency towards slipperiness during heat-sealing.

**[072]** Figures 5 and 5A represent another embodiment of this thermal electrode, called a sealing electrode, that consists of a metal section 50 made of thermally conductive, highly diffusive material. Said section 50 is joined to heating bar 51 made of electrically resistant material. At its extremities heating bar 51 is equipped with electrical connection terminals 52. Metal section 50 has a groove 53 for receiving a heat flux sensor 54. A threaded groove 55 traverses heating bar 51 coaxially in relation to groove 53 to receive head 56 of heat flux sensor 54. A thermocouple 57 is attached in a suitable housing in the sealing electrode consisting of metal section 50.

**[073]** Figure 5A shows how this thermal electrode is attached. Note that heating bar 51 and the metal section are housed in a flexible block 58, with the block itself housed in a support element 59 for the heat-sealing device. The unique feature of this flexible assemblage is its ability to overcome the slipperiness of the elements intervening directly in the heat-sealing process, i.e. the sealing electrode or electrodes and/or the opposing contact element, as the case may be.

**[074]** Figure 6 shows another embodiment of the thermal electrode called the sealing electrode. It consists of a metal section 70 comprising an interior

channel 71 through which cooling fluid circulates on command. The purpose of this channel for the flow of cooling liquid is to control temperature and more specifically, thermal energy transmitted to the material for heat-sealing, thereby regulating the crystallization rate of this material in the sealing zone as it cools. This regulation is particularly important with large seals. Metal section 70 is associated with a thermal capacitor 72. A heat flux sensor 73 is attached between the metal section 70 and thermal capacitor 72.

**[075]** The operation of the heat-sealing electrodes is based on the following principle: when two thermoplastic materials are joined with heat, gradient pressure  $\Delta P$  is applied so as to create a tight contact between these materials. The tight contact created in this way is necessary for the passage of quantities of heat  $\Delta Q$  transmitted by the sealing electrodes, which may be from the hot zones at a temperature  $T_1$  towards the compressed thermoplastic material constituting the cold zone at a temperature  $T_2$  lower than  $T_1$ . The quantities of heat are stored in the thermoplastic material and cause its temperature to rise. The temperature rises until it attains the temperature  $T_F$  at which heat sealing materials melt.

**[076]** From this point on, several phenomena occur. The first one is desirable, that is, auto-adhesion, which is very rapid, of the order of several milliseconds, ensuring molecular bonding between the two materials in the sealing zone.

**[077]** The second one undesirable, that is, flowing, which, due to the sudden change in viscoelasticity in the pressurized sealing zone, tends to reduce the thickness of the material in this same zone, making it mechanically fragile.

**[078]** The third one is the formation of the seal that begins with the cooling of the materials in the sealing zone. At this stage it is known that if cooling can be controlled, the crystallization rate ( $X_c\%$ ) can also be controlled as a function of the slope of the cooling curve. The crystallization rate of the materials affects recrystallization and the shrinking phenomenon that may lead to formation of cracks and serious microbiological flaws in the heat-sealed package when it may subsequently be exposed to mechanical constraints.

- [079] The challenge in heat-sealing consists of regulating these various phenomena. To accomplish this, the invention proposes to effect real time control over the exchange of quantities of heat flowing at a variable rate. According to the prior art, the temperatures were controlled, that is, the final condition, making real time regulation difficult or even impossible.
- [080] As shown in Figure 7, in a variable pattern, heat accumulates over a period of time  $dt$  in sealing zone  $dx$  at temperatures that vary over time. When sealing zone  $dx$  reaches the melting temperature  $T_F$  of the material, sealing zone  $dx$  is the location of energy absorption – PI.
- [081] When sealing zone  $dx$  cools down and reaches the crystallization temperature  $T_C$ , it becomes the location of energy restoration +PI. This variable pattern can be detected with a heat flux sensor correctly positioned on the thermal electrode.
- [082] Figure 8 presents a symbolic schematic of a heat-sealing device. During time  $t + a$  the equivalent thermal capacity  $C_p$  of the heat-sealable materials is charged by sealing electrodes 11 and 12 with quantities of heat  $\Delta Q$  flowing from the hottest point of electrodes 11 and 12 toward the coldest point, sealing zone  $dx$ . Heat fluxes  $\Phi_1$  and  $\Phi_2$  migrate from thermal electrodes 11 and 12 towards sealing zone  $dx$  through thermal resistors  $R_{th}$ . A heat flux sensor 32 measures the variation in thermal flux. The heat fluxes are equal when the temperature of electrodes 11 and 12 is identical, such that  $T_1 = T_2$  and are then nullified when the materials are charged.
- [083] In the example in Figure 8A thermal electrodes 11 and 12 are no longer at the same temperature. For example  $T_1 > T_2$ . The charging fluxes are different:  $\Phi_1 > \Phi_2$ . When the materials are charged, the thermal flux rate is no longer nil. A quantity of heat flow  $\Phi_3$  is established from the hottest electrode 11 at temperature  $T_1$  toward the coldest electrode at temperature  $T_2$  through sealing zone  $dx$ . The flux level  $\Phi_3$  is a function of the difference in temperature between electrodes  $\Delta T = T_1 - T_2$ .
- [084] A heat sensor 32 correctly positioned on electrode 12 will detect a flow  $\Phi_2$

as the material begins charging, and when it has been charged, an inverse flux  $\Phi_3$ .

**[085]** By fixing the temperature of one of the thermal electrodes at a higher value than the melting temperature  $T_F$  in the sealing zone  $dx$  and the temperature of the other thermal electrode at a lower value, the resulting heat flux detected by the heat flux sensor varies constantly as a function of small temperature differences, with the result that for the purpose sought, either the delaminating force or the peeling force is modified, which risks breaking the fragile mechanical seal. This can be overcome and the delaminating and peeling forces stabilized depending upon the various properties of the materials and the environment on the one hand, by regulating the temperature of one electrode using a heat flux regulator operating on the basis of data furnished by the heat flux sensor associated with it and delivering through this electrode only the necessary and sufficient quantities of heat; and on the other hand, by regulating the temperature of the other thermal electrode using a heat flux regulator operating on the basis of data furnished by the heat flux sensor associated with it and delivering through this electrode only the necessary and sufficient quantities of heat.

**[086]** It is therefore possible to make a controlled lid for a package and to regulate the strength of the seal by controlling either the force of delaminating or of peeling through the use of a heat flux regulator to control the thermal electrodes.

**[087]** Figure 9 is a schematic illustration of the means for regulating a thermal electrode 80 associated with a heating bar 81 as a function of the data communicated by heat flux sensor 82. The connecting terminals 84 on heating bar 81 are connected at outputs 85 of a thermofluximetric regulator 86, heat flux sensor 82 is connected to inputs 87 of thermofluximetric regulator 86 by means of its connectors 89, and thermocouple 90 is connected to input 91 of thermofluximetric regulator 86.

**[088]** Flow is prevented in the sealing zone by using heat flux sensor 82 to

detect melting in the zone, with the sensor delivering data processed by thermofluximetric regulator 86 which generates on opto-coupled circuit 92 a signal that passes from 0 to 1. This signal reduces the gradient pressure  $\Delta P$  of cylinder 14 (see Figure 1) on the sealing zone. An opto-coupled output 93 on thermofluximetric regulator 86 passes from 0 to 1 at the same time. This signal controls injection into channel 71 (see Figure 6) on the thermal electrode of a cooling fluid during seal formation.

**[089]** Figure 10 illustrates a series of thermal electrodes 100 with distinct profiles, the sealing surfaces 101 of which may have various possible configurations depending upon the desired application.

**[090]** Figures 11 through 13 illustrate different types of sealing zones obtained using different electrodes. Figure 11 represents a sealing zone with spaced apart points, Figure 12 represents a honeycomb sealing zone, and Figure 13 represents a multilinear sealing zone.

**[091]** In certain instances it is impossible to use juxtaposed thermal electrodes, especially when joining thick pieces, for example, a container 110 and a lid 111 as shown in cross-section in Figure 14. In this case the sealing zone is heated in advance, either by infrared beam or by hot air heat convection.

**[092]** The problems are identical to those described previously. The temperature of the surface of the sealing zone is regulated using a radiant type heat flux sensor 112 and a thermofluximetric regulator as described above.